THE TORNADO AND ITS CAUSE.

By W. J. HUMPHREYS.

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The tornado,[1] in which the air travels in approximate circles, as its name implies, is well-nigh peculiar to the United States east of the Rocky Mountains. Nor is it at all equally distributed over even this area, since it occurs rarely in the Alleghenies, seldom along the Gulf and Atlantic coasts, frequently in central and northern Alabama, Georgia, and South Carolina, frequently also in Ohio, Indiana, Illinois, and southern Michigan, and most frequently in Missouri, Kansas, and Iowa.

The tornado develops only in connection with a thunderstorm, usually just in front of the rain, and especially in connection with those particular storms that form along a valley LOW, or between V-shaped isobars where opposing winds of widely different temperatures give rise to that exceptionally strong vertical convection essential to the genesis and growth of the thunderstorm. The season of most frequent occurrence, therefore, is spring and early summer; in fact, during winter it is unknown, except occasionally near the Gulf and in other warm sections. Similarly, the time of most frequent occurrence is 3 to 5 p. m. Also, since it is only a local phenomenon, while the conditions favorable to its genesis are much more extensive, it often happens that a number of tornadoes develop, even close together, in connection with a single distorted cyclone.

The diameter of the tornado averages only about 300 meters (984 feet); the length of its path varies roughly from 100 meters to possibly 500 kilometers (328 feet to 310 miles); its direction of travel is nearly always northeast; its rate of travel, though differing greatly, averages roughly 11 meters per second (25 miles per hour), thus passing a given place in half a minute or less; while its winds, always counterclockwise, are the swiftest known, estimated at 45 to 225 meters per second (100 to 500 miles per hour). It is therefore by far the smallest, briefest, and severest of all storms. Essentially it is a phenomenon of the middle atmosphere. In its genesis clouds whirl around each other with great velocity and turmoil, while from beneath their center a funnel-shaped cloud develops, usually tapering off to a long pendent spout that may or may not extend to the earth. Wherever it does reach the surface it produces a deafening roar, and practically everything in its immediate narrow path that can be blown down or torn to pieces is destroyed, though generally but little damage is done on either side. On the other hand, wherever it does not come to the surface its passage produces but little or no effect.

Cause.—From the characteristics of the tornado and from the meteorological conditions that normally accompany it, it appears that its origin must be purely mechanical. Thus, its rotation obviously is derived essentially from that of the cyclone in which it occurs, since it is always in the same sense counterclockwise, however small its diameter, and never clockwise, as is often the case with large dust whirls when formed in still air. But how is the rapid rotation started? From the directions of the V-shaped isobars it is clear that at the cloud level, say, there must be, as often observed, neighboring winds flowing in approximately opposite directions and, of course, more or less intermingling and overrunning counter currents. Hence, under such conditions, the inflow occurring at various levels that feeds the strong updraft always just in front of a thunderstorm must occasionally so deflect these countercurrents by drawing both into the same rising column as necessarily to produce a violent whirl.

Here, too, as in all other cases of atmospheric motion, the law of the conservation of areas, or the constancy of the product of radius of curvature by linear velocity, applies, except as modified by friction and viscosity. Hence, as the radii of curvature of the opposing currents may at first be comparatively large, and after the deflection relatively small, it follows that the wind velocity within the whirl in which both the countercurrents are taking part may be very great. This rotation, however, does not check the upcurrent, hence that convection which is essential, as explained above, to the rotation, is maintained, and therefore the rising currents brought in spirally with increasing angular and linear velocity as the axis of spin is approached. Each filament, so to speak, of the spirally-rising air viscously drags along its under and slower neighbors, thereby bringing them nearer the axis and increasing their velocity. In this manner the whole of the rising column is set whirling with greater or less spin. Around the axis of rotation the pressure obviously is reduced in proportion to the centrifugal force, the temperature correspondingly lowered, and therefore a cloud spout often formed.

Wherever the inflow of the surface air is greatly checked, or its course so altered by a deflecting hill or other obstacle as greatly to decrease the spin, there the tornado must lift. It may, however, retain its full vigor in the unaffected upper air, and soon reach the surface again.

Why essentially peculiar to the United States.—Since the tornado rarely occurs in violent form except in that portion of the United States which is east of the Rocky Mountains, it follows that that combination of meteorological conditions essential to its genesis seldom obtains in other parts of the world. This combination appears to be very simple—only a vigorous convection between strong neighboring countercurrents. But since vertical convection, as indicated by thunderstorms, is common enough in most parts of the world, it follows that the other factor—namely, strong countercurrents—is the distinctly American phenomenon. That such currents should often occur east of the Rocky Mountains is obvious from the position and trend of these mountains themselves, giving rise to southward winds, and the location of the Gulf of Mexico, from which winds turn northward. No other similar combination of mountain and ocean wind controls exists, and therefore no other place has in all respects the same kinds, frequencies, and intensities of storms.

[1] For detailed discussion see Finley, "Tornadoes," New York, 1887, and Ferrel, "A Popular Treatise of the Winds," New York, 1889.

Principal Publications Containing Statistics of Tornadoes in the United States.

Finley, J. P. Tornadoes. New York. 1887.

Finley, J. P. Character of six hundred tornadoes. (U. S. Signal Service. Professional paper 7. Washington, 1882.) Gives tabulated statistics, with map, showing distribution of tornadoes in the U. S. 1794–1881, incl.

Flora, S. D. Tornadoes in Kansas. (In U. S. MONTHLY WEATHER REVIEW, v. 43, p. 615–617. Washington. Dec. 1915.)

Hazen, H. A. The tornado. N. Y. 1890.

Henry, A. J. Climatology of the United States. p. 76–80. (U. S. Weather Bureau. Bulletin Q. Washington. 1906.

Henry, A. J. Tornadoes, 1889–1896. (In U. S. Weather Bureau Report of the Chief, 1895–96. p. xxiii–xl.)

Tornadoes in the United States in 1916. Annual report, Chief of Bureau, 1916–17, p. xxxiv–xxxviii, and chart 5.

Tornado frequency per unit area. (In U. S. Weather Bureau. MONTHLY WEATHER REVIEW, v. 25, p. 250–251. Washington, June, 1897.)

Property loss by tornadoes during the period 1889–1897. (In U. S. Weather Bureau. Report of the Chief, 1897–98, p. 304.)

Annual Report of the Chief of the Weather Bureau, beginning 1916–17, contains a section giving descriptions of tornadoes in each State during the year.

Numerous descriptions of individual tornadoes are scattered through the files of the MONTHLY WEATHER REVIEW, published by the U. S. Weather Bureau.

Some of the more important of these are:

St. Louis tornado of May 27, 1896. 1896, Mar., **24**: 77–81.

Omaha tornado of March 23, 1913. 1913, Mar., **41**: 396–397; 481–483.

Tornadoes in Kansas. (Summary.) 1915, Dec., **43**: 615–617.

Characteristics of tornadoes. 1899, Jan., **27**: 157.

Wind force in tornadoes. 1901, Sept., **29**: 419.

Tornadoes in eastern Nebraska. April 6, 1919. 1919. Apr., **47**: 234–236.

Tornado at Fergus Falls, Minn., June 22, 1919. 1919, June, **47**: 392–393.

Kansas tornadoes. 1919, July, **47**: 447–484.

Cyclones should not be confused with tornadoes. 1906, Jan., **34**:165.

Climatological Data for the United States by Sections also contains reports of tornadoes.—*C. F. Talman.*

THE HAILSTORM OF APRIL 8, 1920, IN WASHINGTON COUNTY, ALA.

About 5 p. m. on April 8, 1920, a severe hailstorm occurred in southwestern Washington County near Deer Park and Vinegar Bend, Ala. The storm came up with heavy and black clouds and moved from northwest to southeast, and was accompanied by heavy thunder, high winds, and heavy rainfall, amounting to about 2 inches (estimated). The hail fell over a strip about 3½ miles wide to an average depth of about 2½ inches, and drifted in places to a depth of 3 to 5 feet. The hailstones were about the size of a medium-sized hen's egg, egg-shaped and flat. Windows were broken, fruit was knocked off the trees, and leaves of trees, especially of the magnolia, were cut to shreds. The first hailstones that fell were snowy white; later the hailstones became clearer and more angular than when first observed. These details were kindly furnished by the postmaster at Deer Park, Ala.—*P. H. Smyth.*

CLOUDINESS IN NEW YORK STATE.

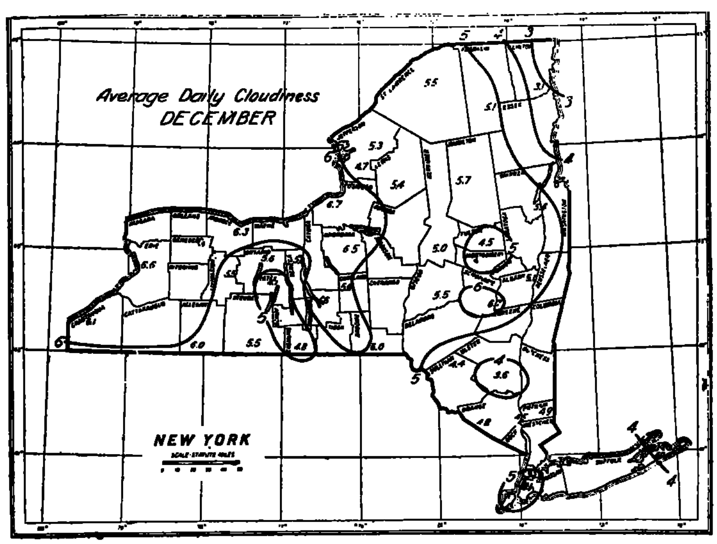
By ERNEST S. CLOWES.

[Bridgehampton, Long Island, N. Y., Apr. 14, 1920.]

With the exception of North Carolina, the State of New York contains a greater range of temperature than any eastern State and it exceeds even North Carolina in the variety of its climatological features. With a seacoast of 250 miles and an approximately equal shore line on the Great Lakes, with elevations varying from sea level to 5,000 feet above, and lying, as it does, in the track of the great majority of storms that cross the American Continent, it offers an opportunity probably unequaled by any similar area in the world for a study of the varied phenomena of weather and climate. In this paper it is only intended to consider the distribution of cloudiness throughout the State as it is typically illustrative of lower cloud formation.

It has long been known that the leeward shores of the Great Lakes are one of the cloudiest regions of the United States, especially during the winter season; and further study goes to show that in all the lake region the cloudiest section is that along the eastern shores of Lake Erie and Lake Ontario where in addition to the situation of a leeward shore is added that of a marked elevation of the land area. At the same time it was recognized that other parts of New York were relatively sunny in winter, and so, in order to partly clear up this rather cloudy situation, this little study was undertaken while the author was at Syracuse, N. Y., in the service of the U. S. Weather Bureau and able to avail himself of the opportunities there offered.

The method employed was as follows: A number of stations, regular and cooperative, were selected with records of clear, partly cloudy, and cloudy days extending back for at least five years. From these records the months of December and June were selected to represent the maximum and minimum of cloudiness, although it is likely that July in some cases would have been nearer the minimum and November to the maximum. A five-year average was then made for each of these stations of the number of clear, partly cloudy, and cloudy days in each of these months. What was most wanted, however, was an expression of the average daily cloudiness. This was secured as follows: As the expression clear means a cloudiness of from 0 to 3 on a scale of 10; partly cloudy from 4 to 7, inclusive, and cloudy from 8 to 10; the average number of clear days was multiplied by 1½, of partly cloudy by 5, and of cloudy by 8½. The sum of the results was divided by 30, giving an expression for average daily cloudiness that was well within the limits of experimental error and which gave a fair basis for comparison. These figures were then inserted on their proper places on the map and lines of equal cloudiness drawn as shown. A contour map of the State with lines drawn at 500, 1,000, and 1,500 feet was also prepared.



Let us first look at the December map. The area of greatest cloudiness covers the entire western half of the State except for a "hump" of relatively clear skies from the southern boundary to the neighborhood of Rochester. Within this "hump" is an oval area covering the counties of Yates, Schuyler, and Chemung with an even less degree of cloudiness: 20 to 30 per cent less than in the section 50 miles to either side. This cloudy belt of western New York is, of course, explained by the prevailing northwest winds rising from the lakes to the high land of the interior which at this season is much colder than the water surface. The relatively clear spot in the